Informational Leaflet 82

BRISTOL BAY RED SALMON FORECAST OF RUN FOR 1966

Edited by:

Frank J. Ossiander
Division of Commercial Fisheries
Research Section
Juneau, Alaska

June 15, 1966

STATE OF ALASKA
WILLIAM A. EGAN - GOVERNOR

DEPARTMENT OF
FISH AND GAME
WALTER KIRKNESS - COMMISSIONER
SUBPORT BUILDING, JUNEAU

Summary of Forecasts of the Bristol Bay Red Salmon Run in 1966 (in millions of fish).

	.2-ocean	.3-ocean1/	total
Forecast by River System			
Togiak	.091	.222	.313
Igushik	.139	.414	.553
Snake	.007	.004	.011
Nuyakuk	.037	.204	.241
Wood	1.950	.466	2.416
Nushagak-Mulchatna	.002	.045	.047
Nushagak Sub-total	2.135	1.133	3.268
Kvichak	14.819	6.408	21.227
Naknek	.515	1.352	1.867
Alagnak	.104	.087	.191
Naknek-Kvichak Sub-total	15.438	7.847	23.285
Egegik	1.338	1.837	3.175
Ugashik	.366	.864	1.230
North Side Alaska Peninsula	.834	.549	1.383
River System Total	20.202	12.452	32.654
High Seas Purse Seine	10.4	23.6	34.0
Relation of .3-ocean returns to .2-ocean returns		19.654	
Ratio estimate of .2-ocean return	8.4		

1/ The .3-ocean return has been adjusted by subtracting the Japanese high seas catch of immature red salmon in 1965.

BRISTOL BAY RED SALMON FORECAST

OF RUN FOR 1966

Edited by:

Frank J. Ossiander, Biometrician
Alaska Department of Fish and Game
Division of Commercial Fisheries
Research Section
Juneau, Alaska

I. Introduction

The forecast for the 1966 Bristol Bay red salmon run was prepared jointly by the Fisheries Research Institute of the University of Washington, the U.S. Bureau of Commercial Fisheries and the Alaska Department of Fish and Game.

The following scientists participated in the analysis of the data: Dr. Robert L. Burgner, Mr. Allen C. Hartt, Mr. Stephen B. Matthews and Dr. William F. Royce of the Fisheries Research Institute; Dr. Charles J. DiCostanzo, Mr. Reynold A. Fredin, Dr. L. Henrich and Mr. H. Jaenicke of the U.S. Bureau of Commercial Fisheries; Mr. Frank J. Ossiander of the Alaska Department of Fish and Game.

A draft of the 1966 forecast was compiled in October, 1965, using preliminary data on the 1965 run. This forecast uses final 1965 run data from all river systems in Bristol Bay.

II. Methods of Forecast

Forecasts are made of the expected return to the major river systems in each fishing district of Bristol Bay and of the expected return to Bristol Bay as a whole. Data used in these forecasts are: the inshore abundance and age composition of the catch and escapement, smolt outmigration age composition, the Japanese high seas catch and age composition of western Alaska red salmon, and purse seine catches of immature red salmon south of Adak Island.

Forecasts are based on the relationship of return to abundance at some preceding stage of the red salmon life cycle. For the separate river system

forecasts the relationship of escapement to subsequent return and the relationship of smolt outmigration to return are used. The maturity schedule is estimated using smolt age and ocean age composition. A forecast of the total red salmon run to western Alaska is based on the previous year's purse seine index catch of immature red salmon south of Adak Island. Each of these methods has led to the analysis of population data and the development of forecast equations based on selected key factors. By this it is suggested that changes in population density, although affected to some extent by many variables, may be essentially determined by only a few variables. The method of analysis usually employed involves only simple linear regression analysis or multiple regression analysis. Along with desirable features there are shortcomings and limitations in this type of analysis. The key factor model may not utilize all information available and many factors affecting abundance may not be represented in a key factor equation. The key factor relationships essentially provide only measures of gross survival rates between the particular factors used. For forecasting purposes it is necessary to choose key factors which are separated by an interval over which the survival rates are most nearly constant from year to year.

In the following sections data and relationships for each forecast method are given. These relationships depend upon the adequacy of the basic data which is influenced by sampling errors and the representativeness of the sampling plans. Additional inaccuracies arise from not having sufficient data on the Japanese high seas catch of red salmon to adequately prorate their catch to the inshore river systems. Other assumptions and rationale are given in the particular forecast section.

III. Estimation of Total Returns to Each River System

The total returns to Bristol Bay are composed of the inshore catch and escapement and the fish which would be expected to return if they were not intercepted by a high seas fishery. As a first step in forecast analysis it is necessary to assign this total return to its target river system. The inshore catch and escapement data is obtained within districts for which target river systems can be directly assigned. The high seas fishery takes fish of many different origins; however, from tagging and experimental fishery studies of the migration and distribution of red salmon in the ocean it has been established that at certain times and in certain areas the Japanese high seas fishery catches red salmon bound for Bristol Bay. For mature red salmon these times and areas include the May and June 1-10 catches east of 170° E, the June 11-20 catches east of 175° E, and the June 21-30 catches east of 180°. For immature red salmon it includes the July and August catches east of 170°, and the June 21-30 catches between 170° E and 180°.

Total catch data for the Japanese high seas fishery is available for all years, but the age structure is available for only five years and it must be esti-

mated for the remaining years. The total run (inshore returns plus high seas catches) to each river system is estimated by separating the yearly Japanese high seas catch according to ocean age and then adding it to each river's inshore return on the basis of each river's contribution to the particular ocean age of this yearly Bristol Bay return.

The age structure of the Japanese high seas catches of red salmon at times and in areas which are predominately Bristol Bay fish is given in Table 1 along with inshore age data. This data is used in a regression analysis to obtain an estimate of the age structure of the total return for those years for which data is not available. The relation is illustrated in Figure 1.

The Japanese high seas catches of mature red salmon were assumed to return to Bristol Bay in the same year as .2-ocean and .3-ocean age fish, the catches of immatures were assumed to return to Bristol Bay as .3-ocean age fish in the following year. The formulas used to apportion the total return are:

For the .2-ocean age return,

$$(1) \qquad R_{ij2} = R_{i\,.2} \frac{r_{ij2}}{r_{i\,.2}}$$

and for the .3-ocean age return,

$$(2) \qquad R_{ij3} = R_{i\,.3} \frac{r_{ij3}}{r_{i\,.3}}$$

where,

R_{ijk} : total return to Bristol Bay in year i to river j of ocean age k (k = 2,3),

r_{ijk} : inshore return to Bristol Bay in year i to river j of ocean age k

The dot subscript indicates summation over the subscript it replaces.

This procedure makes no allowance for ocean mortality which would be expected to apply between the time fish are taken on the high seas and when they would have returned to Bristol Bay. Likewise, no drop-out (a drop-out is considered a fish which falls from the gear as a dead fish or subsequently dies because of its encounter with the gear, it is lost from the fishery) factor is applied to the Japanese high seas fishery. Additional errors probably arise because of changes from year to year in the migratory pattern of red salmon in the ocean; consequently, affecting the estimates of high seas catches of Bristol Bay red salmon.

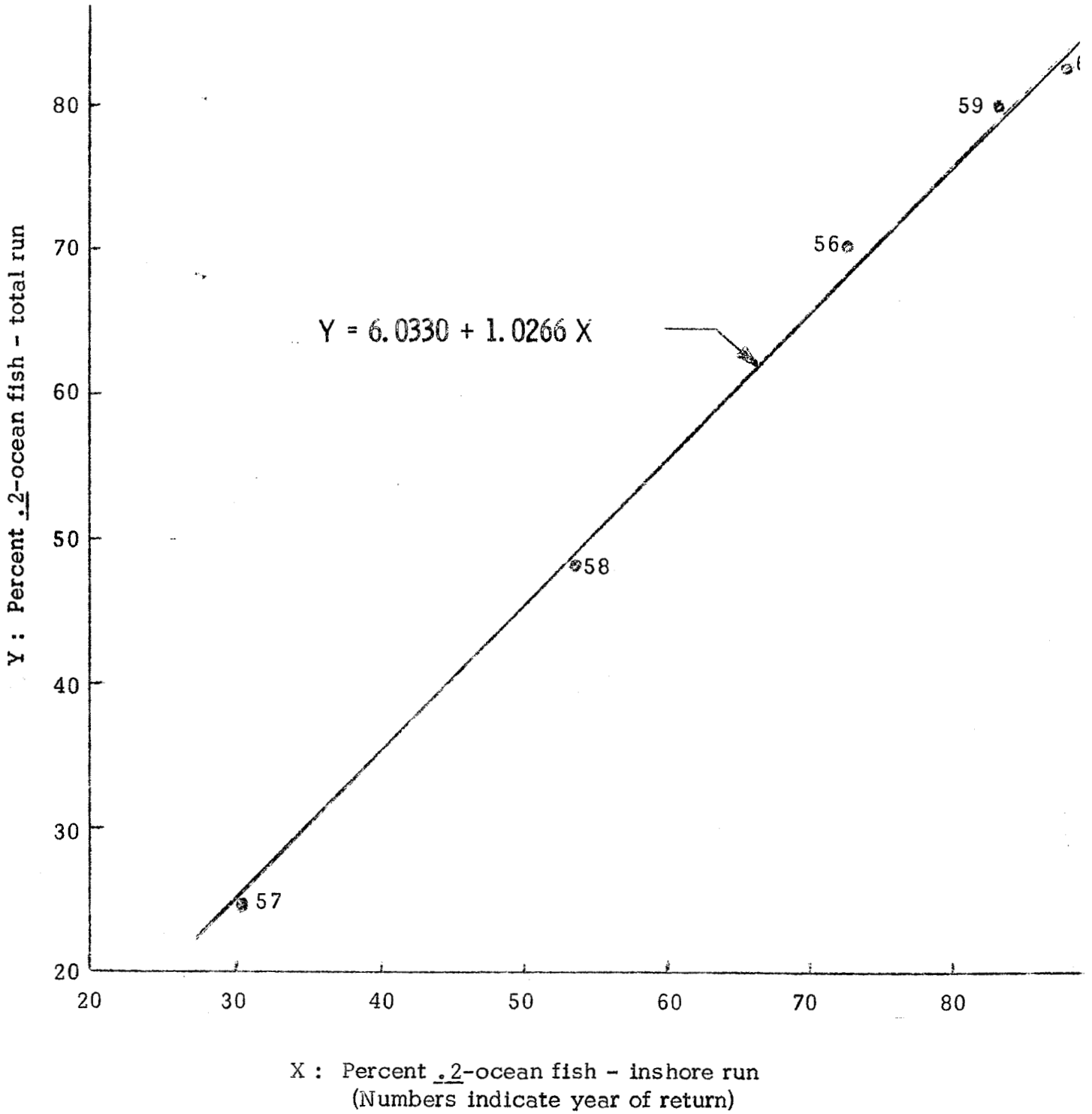

Figure 1. Relation between percent .2-ocean fish in inshore run and percent .2-ocean fish in total run, 1956 to 1960.

It is assumed that the Japanese catch an equal proportion of each river's fish in the .2-ocean and .3-ocean age classes. Errors may also arise because of incomplete data on the age composition of the high seas catches.

The inshore return data is given in Table 2, the high seas catches in Table 3 and the apportioned Bristol Bay return is given in Table 4.

IV. River System Forecasts

Forecasts to each river system are based on the relationships of returns to escapements and returns to smolt outmigrations. The 1966 maturity schedule is estimated from the weighted age composition for those river systems for which no smolt outmigration data is available and for those river systems for which smolt outmigration data is available it is estimated using a 2 x 2 contingency table composed of the smolt outmigration age classes and the ocean age classes. This table is constructed as follows:

Brood year		Smolt age classes		Total ocean age classes
		1-check	2-check	
ocean age classes	.2-ocean	P (4_2)	P (5_3)	P (.2-ocean)
	.3-ocean	P (5_2)	P (6_3)	P (.3-ocean)
Total smolt age classes		P(1-check)	P(2-check)	1.00

where,

P (x) : indicates the probability of the particular age composition.

The equations used for each of the river system forecasts are:

(1) $R = a + b\,S$

(2) $R = a + b\,E$

(3) $R = a\,E^2\,10^{-bE}$

where,

R: is adult return

E: is escapement

S: is smolt outmigration index

a and b: are parameters to be determined from the data.

In the Nushagak and Naknek-Kvichak fishing districts the red salmon return to several separate spawning systems. Since the commercial catch is taken in the respective bays it cannot be separated directly into parts bound for the separate spawning systems. Therefore, the catch has been prorated to the separate spawning systems on the basis of the escapement by age groups to each river system.

Table 1. ESTIMATES OF .2-OCEAN AGE COMPOSITION OF TOTAL RUN.

Return Year	JAPANESE HIGH SEAS FISHERY									INSHORE RUN			TOTAL RUN		
	May			June			May and June								
	Total Catch	Percent .2-ocean	Catch .2-ocean	Total Catch	Percent .2-ocean	Catch .2-ocean	Total Catch	Percent .2-ocean	Catch .2-ocean	Total	Percent .2-ocean	Return .2-ocean	Total	Percent .2-ocean	Return .2-ocean
1956	1,381	43	566	1,371	61	836	2,752	51	1,402	27,474	72.60	19,945	30,286	70.48	21,347
1957	2,051	19	390	5,609	25	1,402	7,660	23	1,792	12,008	30.20	3,626	21,743	24.92	5,418
1958	584	16	93	430	46	198	1,014	29	291	6,618	53.79	3,560	7,974	48.29	3,851
1959	385	35	135	685	65	445	1,070	54	580	14,057	83.29	11,708	15,278	80.43	12,288
1960	208	28	58	3,799	54	2,051	4,007	53	2,109	37,453	87.37	32,724	42,645	81.68	34,833
1961	546	--	--	5,875	--	---	6,421	--	---	18,886	35.04	6,618	26,274	29.94[1]	7,866[2]
1962	475	--	--	840	--	---	1,315	--	---	10,889	69.95	7,617	12,266	65.78[1]	8,069[2]
1963	92	--	--	924	--	---	1,016	--	---	7,331	57.54	4,218	8,617	53.04[1]	4,570[2]
1964	357	--	--	257	--	---	614	--	---	11,942	77.09	9,206	13,386	73.11[1]	9,787[2]
1965	---	--	--	---	--	---	6,163	--	---	55,055	91.09	50,150	63,055	87.48[1]	55,151[2]

1/ Percentage .2-ocean red salmon in total run for the years 1961-1965 estimated using equation,

$$Y = -6.0330 + 1.0266\ X$$

see Figure 1.

2/ .2-ocean return for the years 1961-1965 calculated using percentage obtained from equation,

$$Y = 6.0330 + 1.0266\ X.$$

Table 2. BRISTOL BAY INSHORE RETURNS (In Thousands of Fish)

Year of Run	Igushik	Snake	Nuyakuk	Wood	Mulchatna	Kvichak	Naknek	Alagnak	Egegik	Ugashik	Togiak System	North Side Peninsula	Age Class Total	Yearly Total	Year of Run
						.2-OCEAN									
1956	206	5	8	966	0	13,799	926	835	770*	508*	203	1,719*	19,945	27,474	1956
1957	67	2	38	206	0	1,962	81	174	168	375*	142*	411*	3,626	12,008	1957
1958	50	12	54	1,266	0	411	242	66	428	411	26	594*	3,560	6,618	1958
1959	627	212	72	3,325	0	851	2,753	1,124	1,393	400	155	796*	11,708	14,057	1959
1960	253	17	205	1,059	0	22,517	622	1,730	2,520	2,963	126	712*	32,724	37,453	1960
1961	11	1	3	119	0	5,036	43	4	724	86	41	550*	6,618	18,886	1961
1962	30	4	85	1,958	1	3,067	555	80	1,025	375	92	345*	7,617	10,889	1962
1963	105	60	36	909	5	300	770	284	829	402	166	352*	4,218	7,331	1963
1964	146	20	146	1,750	2	1,454	2,059	217	1,434	940	235	803*	9,206	11,942	1964
1965	66	6	52	321	7	41,678	828	199	4,022	1,596	103	1,272*	50,150	55,055	1965
						.3-OCEAN									
1956	683	3	61	506	21	384	2,607	529	1,431	254	124	926	7,529		1956
1957	194	4	96	358	22	4,621	1,424	109	1,035	187	110	222	8,382		1957
1958	202	3	432	336	8	656	285	123	312	299	82	320	3,058		1958
1959	313	10	4	163	31	84	477	108	333	229	168	429	2,349		1959
1960	793	13	9	800	39	89	1,252	336	725	84	205	384	4,729		1960
1961	452	6	119	579	54	5,522	1,308	369	2,664	620	279	296	12,268		1961
1962	62	0	10	223	10	1,347	551	53	637	121	73	185	3,272		1962
1963	76	1	261	330	62	260	748	33	857	174	122	189	3,113		1963
1964	173	7	64	401	31	136	488	296	498	98	112	432	2,736		1964
1965	248	14	312	821	43	433	1,001	196	602	323	227	685	4,905		1965

* Estimated age composition.

Table 3. Japanese High Seas Catches of Red Salmon Bound for Bristol Bay (In Thousands of Fish)

Year	Matures 1/	Immatures 2/	Total
1952	367	34	401
1953	406	0	406
1954	600	0	600
1955	1,869	60	1,929
1956	2,752	2,075	4,827
1957	7,660	342	8,002
1958	1,014	151	1,165
1959	1,070	1,185	2,255
1960	4,007	967	4,974
1961	6,421	62	6,483
1962	1,315	270	1,585
1963	1,016	830	1,846
1964	614	1,837	2,451
1965	6,168	776	6,944

1/ Includes the May and June 1-10 catches east of 170° E, the June 11-20 catches east of 175° E, and the June 21-30 catches east of 180°.

2/ Includes red salmon taken on high seas at times and in areas where immature Bristol Bay reds are in large majority. These are mostly .2 age fish that otherwise would be expected to mature and return to Bristol Bay as .3's. Includes July and August catches east of 170°, and June 21-30 catches between 175° E and 180°.

Table 4. BRISTOL BAY TOTAL RETURNS, APPORTIONED FOR JAPANESE HIGH SEAS CATCHES (In Thousands of Fish)

Year of Run	Igushik	Snake	Nuyakuk (Tikchik)	Wood	Mulchatna	Kvichak	Naknek	Alagnak	Egegik	Ugashik	Togiak & Tributaries	North Side Alaska Pen.	Age Class Total	Yearly Total	Year of Run
								.2-OCEAN							
1956	220	5	9	1,034	0	14,769	991	894	824	544	217	1,840	21,347	30,286	1956
1957	100	3	57	308	0	2,932	121	260	251	560	212	614	5,418	21,743	1957
1958	54	13	58	1,369	0	445	262	71	463	445	28	643	3,851	7,974	1958
1959	658	223	75	3,490	0	893	2,889	1,180	1,462	420	163	835	12,288	15,278	1959
1960	270	18	219	1,127	0	23,968	662	1,841	2,682	3,154	134	758	34,833	42,645	1960
1961	13	1	4	141	0	5,986	51	5	860	102	49	654	7,866	26,274	1961
1962	32	4	90	2,074	1	3,249	589	85	1,086	397	97	365	8,069	12,266	1962
1963	114	65	39	985	5	325	834	308	898	436	180	381	4,570	8,617	1963
1964	155	21	155	1,860	2	1,546	2,189	231	1,525	999	250	854	9,787	13,386	1964
1965	73	7	57	353	8	45,842	911	219	4,424	1,755	113	1,399	55,161	63,055	1965
								.3-OCEAN							
1956	811	4	72	601	25	456	3,095	628	1,699	302	147	1,099	8,939		1956
1957	378	8	187	697	43	9,000	2,773	212	2,016	364	214	433	16,325		1957
1958	272	4	582	453	11	884	385	166	421	403	111	431	4,123		1958
1959	398	13	5	208	39	107	608	137	424	291	214	546	2,990		1959
1960	1,310	21	15	1,322	64	147	2,068	555	1,198	139	339	634	7,812		1960
1961	678	9	179	869	81	8,286	1,963	554	3,997	930	418	444	18,408		1961
1962	79	0	13	286	13	1,728	707	68	817	155	94	237	4,197		1962
1963	99	1	339	429	81	338	972	43	1,114	226	159	246	4,047		1963
1964	228	9	84	527	41	179	642	389	655	129	147	569	3,599		1964
1965	400	23	502	1,321	69	697	1,611	315	969	520	365	1,102	7,894		1965

Table 5. Togiak River - Escapements and Returns, in Thousands of Fish

Brood Year	Escapement	Inshore Return by age class				Total Return by age class				Total
		4_2	5_3	5_2	6_3	4_2	5_3	5_2	6_3	
1951	51	34	52	97	16[1/]	34[2/]	56	115	20	225
1952	102	150	16[1/]	152[1/]	5	161	40	194	7	402
1953	102	68[1/]	8	77	17	172	9	104	22	307
1954	57	18	13	151	17	19	14	192	29	254
1955	104	143	9	185	7	149	10	310	11	480
1956	225	113	7	271	1	124	9	407	1	541
1957	25	33	1	71	29	40	1	93	38	172
1958	72	90	49	93	23	96	53	121	31	301
1959	179	116	53	86	5	127	57	116	9	309

1/ Return by age class estimated from average age composition.

2/ Return by age class not corrected for Japanese high seas catch.

Table 6. Togiak River - Estimated Return in 1966 From Brood Years 1960, 1961 and 1962 in Thousands of Fish.

Brood Year	Escapement	Estimated Return[1]	Estimated Return in 1966 by age class[2]				
			4_2	5_3	5_2	6_3	Total
1960	163	453				29	29
1961	95	337		22	203		225
1962	47	255	69				69
Total return in 1966							323

1/ Estimated returns obtained from equation:

$R = 175.029 + 1.703\ E$

2/ Estimated return by age class based on average age composition.

Table 7. Igushik River Escapements and Returns, in Thousands of Fish

Brood Year	Escapement	Inshore Return by age class				Total Return by age class				Total
		4_2	5_3	5_2	6_3	4_2	5_3	5_2	6_3	
1947	350	1	2	364	9	1[1/]	2[1/]	364[1/]	9[1/]	376
1948	300	22	11	113	2	22[1/]	11[1/]	113[1/]	2[1/]	148
1949	20	21	1	42	0	21[1/]	1[1/]	42[1/]	0[1/]	64
1950	75	75	51	198	76	75[1/]	51[1/]	198[1/]	183	507
1951	40	499	61	606	17	499[1/]	65	628	33	1,225
1952	150	145	6	177	19	155	9	345	26	535
1953	100	61	5	183	61	91	5	246	78	420
1954	80	45	195	251	100	49	205	320	166	640
1955	500	432	102	691	69	453	110	1,144	103	1,810
1956	400	152	9	383	29	160	11	575	43	789
1957	130	2	16	24	17	2	22	36	22	82
1958	107	7	17	60	25	10	19	77	34	140
1959	644	87	87	145	17	95	93	194	28	410

1/ Return for age class not corrected for Japanese high seas catch.

Table 8. Igushik River - Estimated Return in 1966 From Brood Years 1960, 1961 and 1962 in Thousands of Fish.

Brood Year	Escapement	Estimated Return[1]	Estimated Return in 1966 by age class[2] 4_2	5_3	5_2	6_3	Total
1960	495	757				76	76
1961	294	604		50	357		407
1962	16	392	89				89
Total return in 1966							572

1/ Estimated returns obtained from equation:

$R = 380 + 0.762\ E$

2/ Estimated return by age class based on average age composition.

Table 9. Snake River - Escapements and Returns, in Thousands of Fish

Brood Year	Escapement	Inshore Return by age class				Total Return by age class				Total
		4_2	5_3	5_2	6_3	4_2	5_3	5_2	6_3	
1950	4.0	4.8	3.4	7.3	0.3	4.8[1/]	3.4[1/]	7.3[1/]	0.3[1/]	16.0
1951	3.0	33.7	1.4	2.2	0.3	33.7[1/]	1.5	3.5	0.6	39.3
1952	4.0	3.3	0.2	3.6	0.3	3.5	0.3	7.4	0.4	11.6
1953	4.0	2.0	1.2	2.6	2.0	2.7	1.3	3.6	2.5	10.1
1954	4.0	11.2	65.8	8.3	1.0	11.7	69.3	10.5	1.6	93.1
1955	30.0	146.0	5.9	12.1	1.1	153.7	6.1	19.4	0.7	179.9
1956	4.0	11.4	0.2	4.8	0	11.9	0.2	7.3	0	19.4
1957	3.0	1.1	0.1	0	0	1.1	0.1	0	0	1.2
1958	9.0	3.9	1.2	1.0	0.2	3.9	1.3	1.0	0.3	6.5
1959	14.0	59.0	6.3	6.8	0.9	63.7	6.6	8.7	1.3	80.3

1/ Return by age class not corrected for Japanese high seas catch.

Table 10. Snake River - Estimated Return in 1966 From Brood Years 1960, 1961 and 1962 in Thousands of Fish.

Brood Year	Escapement	Estimated Return[1]	Estimated Return in 1966 by Age Class[2]				
			4_2	5_3	5_2	6_3	Total
1960	17	62				1	1
1961	5	18		3	3		6
1962	2	7	4				4
Total return in 1966							11

1/ Estimated return obtained from the geometric mean of the return per spawner.

2/ Estimated return by age class based on average age composition.

Table 11. Nuyakuk River - Escapements and Returns, in Thousands of Fish

Brood Year	Escapement	Inshore Return by age class				Total Return by age class				Total
		4_2	5_3	5_2	6_3	4_2	5_3	5_2	6_3	
1946	432	20	3	62	1	20[1/]	3[1/]	62[1/]	1[1/]	85
1947	325	7	4	29	20	7[1/]	4[1/]	29[1/]	20[1/]	60
1948	303	56	6	260	2	56[1/]	6[1/]	260[1/]	2[1/]	324
1949	14	12	1	31	0	12[1/]	1[1/]	31[1/]	0[1/]	43
1950	42	14	1	9	7	14[1/]	1[1/]	9[1/]	8	32
1951	39	13	2	55	8	13[1/]	2	64	16	95
1952	38	6	3	87	40	7	4	171	54	236
1953	189	35	5	391	1	53	5	528	1	587
1954	29	48	22	4	0	53	23	4	0	80
1955	16	50	9	9	0	52	10	15	0	77
1956	30	196	0	119	0	209	0	179	0	388
1957	67	3	1	10	1	4	1	13	1	19
1958	196	84	27	260	11	89	28	338	14	469
1959	49	10	3	54	7	11	3	70	12	96

1/ Return by age class not corrected for Japanese high seas catch.

Table 12. Nuyakuk River - Estimated Return in 1966 From Brood Years, 1960, 1961 and 1962 in Thousands of Fish.

Brood Year	Escapement	Estimated Return[1]	Estimated Return in 1966 by Age Class[2]				
			4_2	5_3	5_2	6_3	Total
1960	146	378				19	19
1961	80	284		10	194		204
1962	38	115	27				27
Total return in 1966							250

1/ Estimated returns obtained from equation:

$$R = 135.21\ E^2\ 10^{-6.044056\ E}$$

2/ Estimated return by age class based on average age composition.

Table 13. Wood River - Escapements and Return, in Thousands of Fish

Brood Year	Escapement	Inshore Return by age class				Total Return by age class				Total
		4_2	5_3	5_2	6_3	4_2	5_3	5_2	6_3	
1950	452	706	160	348	57	706[1/]	160[1/]	348[1/]	68	1,282
1951	458	1,560	286	449	31	1,560[1/]	306	533	61	2,460
1952	227	680	18	326	31	728	27	636	42	1,433
1953	516	188	128	304	32	281	138	411	41	871
1954	571	1,138	1,033	131	59	1,231	1,084	167	98	2,580
1955	1,383	2,292	360	738	105	2,406	383	1,224	162	4,175
1956	773	698	18	459	0	744	21	707	0	1,472
1957	289	102	31	223	0	120	33	286	0	439
1958	960	1,927	65	328	30	2,041	67	429	40	2,577
1959	2,209	885	345	370	41	918	367	487	67	1,839

1/ Return by age class not corrected for Japanese high seas catch.

Table 14. Wood River - Estimated Return in 1966 From Brood Years 1960, 1961 and 1962 in Thousands of Fish.

Brood Year	Escapement	Estimated Return[1]	Estimated Return in 1966 by Age Class[2]				
			4_2	5_3	5_2	6_3	Total
1960	1,016	2,902				70	70
1961	461	1,528		96	417		513
1962	874	2,730	1,854				1,854
Total return in 1966							2,437

1/ Estimated returns obtained from equation:

$$R = 15.621\ E^2\ 10^{-0.733047\ E}$$

2/ Estimated return by age class based on 2 x 2 contingency table.

Table 15. Nushagak-Mulchatna River - .2-ocean and .3-ocean Returns and Estimated Return in 1966

Return Year	.2-ocean Return	.3-ocean Return
1956	0	25
1957	0	43
1958	0	11
1959	0	39
1960	0	64
1961	0	81
1962	1	13
1963	5	81
1964	2	41
1965	8	69
1966	2 1/	47 1/

1/ Estimated return obtained from the arithmetic mean of the .2-ocean and .3-ocean returns.

Table 16. Kvichak River - Smolt Indices and Returns in Thousands of Fish.

Year of Outmigration	Smolt Index[1]	Return in thousands of fish .2-ocean	.3-ocean
1955	7.8	2,932	884
1956	2.3	445	107
1957	0.9	893	147
1958	100.0	23,968	8,286
1959	85.9	5,986	1,728
1960	18.4	3,249	338
1961	1.1	325	179
1962	36.1	1,546	697
1963	126.9	45,842	6,909 [3]
1964	61.8	14,819 [2]	

1/ Based on the estimation of the 24-hour daily smolt seaward outmigration.

2/ .2-ocean return estimated using equation,

$$R = -2.02356 + 0.27253\ S.$$

3/ .3-ocean return estimated using equation

$$R = -0.22996 + 0.05626\ S.$$

Table 17. Naknek River - Escapements and Returns, in Thousands of Fish

Brood Year	Escapement	Inshore Return by age class				Total Return by age class				Total
		4_2	5_3	5_2	6_3	4_2	5_3	5_2	6_3	
1953	285	15	163	124	193	22	177	168	247	614
1954	799	78	2,027	283	522	85	2,159	361	863	3,468
1955	279	686	194	729	64	730	206	1,205	96	2,237
1956	1,773	429	2	1,242	264	456	2	1,867	340	2,665
1957	635	39	454	285	569	49	482	367	740	1,638
1958	278	101	465	178	157	107	506	232	208	1,053
1959	2,232	301	709	328	530	328	755	434	854	2,371

Table 18. Naknek River - Estimated Return in 1966 From Brood Years 1960, 1961 and 1962 in Thousands of Fish

Brood Year	Escapement	Estimated Return[1]	Estimated Return in 1966 by Age Class[2]				
			4_2	5_3	5_2	6_3	Total
1960	828	3,319				984	984
1961	351	1,373		266	430		696
1962	723	3,042	249				249
Total return in 1966							1,929

1/ Estimated returns obtained from equation:

$$R = 20.657\ E^2\ 10^{-0.761330\ E}$$

2/ Estimated return by age class based on 2 x 2 contingency table.

Table 19.Alagnak River - Escapements and Returns, in Thousands of Fish

Brood Year	Escapement	Inshore Return by age class				Total Return by age class				Total
		4_2	5_3	5_2	6_3	4_2	5_3	5_2	6_3	
1955	166	750	24	210	32	787	26	347	48	1,208
1956	785	1,707	0	336	20	1,815	0	506	39	2,360
1957	125	4	22	15	11	5	35	29	14	83
1958	91	32	23	22	48	50	25	29	63	167
1959	825	260	117	247	57	283	129	326	92	830

Table 20. Alagnak River - Estimated Return in 1966 from Brood Years 1960, 1961 and 1962, in Thousands of Fish.

Brood Year	Escapement	Estimated Return[1]	Estimated Return in 1966 by Age Class[2]				
			4_2	5_3	5_2	6_3	Total
1960	1,241	919				51	51
1961	90	150		7	40		47
1962	91	153	97				97
Total return in 1966							195

1/ Estimated return obtained from equation:

$$R = 24.216\ E^2\ 10^{-1.295998\ E}.$$

2/ Estimated return by age class based on average age composition.

Table 21. Egegik River - Escapements and Returns, in Thousands of Fish

Brood Year	Escapement	Inshore Return by Age Class					
		4_2	5_3	6_4	5_2	6_3	7_4
1944	310	159	23	46	23	347	32
1945	530	0	13	96[1/]	0	447[1/]	5
1946	660	0	750[1/]	0	144[1/]	391	11
1947	910	128[1/]	1,205	112	25	547	58
1948	890	5	972	21	96	1,323	8
1949	920	11	317	70	183	352	24[1/]
1950	630	16	347	26[1/]	19	785[1/]	13
1951	950	87	593[1/]	1	622[1/]	761	6
1952	757	151[1/]	151	18	260	271	5
1953	519	16	400	242	36	316	11
1954	507	10	1,133	78	12	570	33
1955	271	19	609	4	145	291	5
1956	1,104	1,833	692	1	2,340	594	10
1957	391	28	986	60	38	784	58
1958	246	38	706	15	62	287	2

1/ Age class of return estimated from average age composition.

Table 22. Egegik River - Escapements and Returns, in Thousands of Fish

Brood Year	Escapement	Total Return by Age Class [1]						
		4_2	5_3	6_4	5_2	6_3	7_4	Total
1944	310	159	23	46	23	347	32	630
1945	530	0	13	96[2]	0	447[2]	5	561
1946	660	0	750[2]	0	144[2]	391	11	1,296
1947	910	128[2]	1,205	112	25	547	58	2,075
1948	890	5	972	21	96	1,323	8	2,425
1949	920	11	317	70	183	352	28[2]	961
1950	630	16	347	27[2]	19	933[2]	25	1,367
1951	950	87	635[2]	1	738[2]	1,484	8	2,953
1952	757	162[2]	226	19	507	356	6	1,276
1953	519	24	433	254	48	403	18	1,180
1954	507	11	1,188	83	15	941	50	2,288
1955	271	20	648	5	239	437	6	1,355
1956	1,104	1,951	822	1	3,510	762	13	7,059
1957	391	33	1,045	65	49	1,020	76	2,288
1958	246	40	765	16	81	378	3	1,283

1/ The returns prior to 1956 are not corrected for Japanese high seas catch.

2/ Age class of return estimated from average age composition.

Table 23. Egegik River - Estimated Return in 1966 From Brood Year 1960, 1961 and 1962 in Thousands of Fish

Brood Year	Escapement	Estimated Return[1]	Estimated Return in 1966 by Age Class[2]						
			4_2	5_3	6_4	5_2	6_3	7_4	Total
1959	1,072	3,382						27	27
1960	1,799	5,818			105		1,466		1,571
1961	702	2,142		819		428			1,319
1962	1,027	3,231	342						342
Total return in 1966									3,259

1/ Estimated returns obtained from equation:

$$R = -0.210 + 3.351\ E\ .$$

2/ Estimated return by age class based on average age composition.

Table 24. Ugashik River - Escapements and Returns, in Thousands of Fish

Brood Year	Escapement	Inshore Return by age class				Total Return by age class				Total
		4_2	5_3	5_2	6_3	4_2	5_3	5_2	6_3	
1953	1,056	---	386	228	202	61[1/]	421	307	258	1,047
1954	459	22	376	26	54	24	403	33	90	550
1955	77	16	107	29	5	17	114	49	8	188
1956	425	2,857	60	614	30	3,040	71	922	38	4,071
1957	215	26	318	91	85	31	337	117	110	595
1958	298	57	383	89	61	60	420	116	82	678
1959	219	15	296	35	99	16	315	47	160	538
1960	2,331	644	1,384	222	---	684	1,521	360	552[1/]	3,117

1/ Age class of return estimated from average age composition.

Table 25. Ugashik River - Estimated Return in 1966 From Brood Years 1960, 1961 and 1962 in Thousands of Fish

Brood Year	Escapement	Estimated Return	Estimated Return in 1966 by Age Class 3/ 4_2	5_3	5_2	6_3	Total
1960	2,331	3,117 1/				552 1/	552
1961	366	1,191 2/		65	351		416
1962	274	776 2/	301				301
Total return in 1966							1,269

1/ 6_3 age class of return estimated from average age composition.

2/ Estimated return obtained from equation:

$$R = 16.314\ E^2\ 10^{-0.720848\ E}$$

3/ Estimated return by age class based on 2 x 2 contingency table.

Table 26. North Side Alaska Peninsula - .2-ocean and .3-ocean Returns and Estimated Return in 1966

Return Year	.2-ocean Return	.3-ocean Return
1956	1,840	1,099
1957	614	433
1958	643	431
1959	835	546
1960	758	634
1961	654	444
1962	365	237
1963	381	246
1964	854	569
1965	1,399	1,102
1966	834 1/	574 1/

1/ Estimated return obtained from the arithmetic mean of the .2-ocean and .3-ocean returns.

Table 27. Summary of the River System Forecast of the Bristol Bay Red Salmon Run for 1966 (in thousands of fish).

River System	.2-Ocean	.3-Ocean [1]	Total
Togiak	91	222	313
Igushik	139	414	553
Snake	7	4	11
Nuyakuk	37	204	241
Wood	1,950	466	2,416
Nushagak-Mulchatna	2	45	47
Nushagak Sub-total	2,135	1,133	3,268
Kvichak	14,819	6,408	21,227
Naknek	515	1,352	1,867
Alagnak	104	87	191
Naknek-Kvichak Sub-total	15,438	7,847	23,285
Egegik	1,338	1,837	3,175
Ugashik	366	864	1,230
North Side Alaska Peninsula	834	549	1,383
Total	20,202	12,452	32,654

1/ The .3-ocean return has been adjusted by subtracting the Japanese high seas catch of immature red salmon in 1965.

V. Forecast of Total Run Based on High Seas Purse Seine Catches

The forecast of the total run to western Alaska in 1966 based on the 1965 purse seine indexing of immature red salmon south of Adak is as follows:

.2-ocean age:	10.4 million
.3-ocean age:	24.4 million
total	34.8 million

The above figures are based on a regression analysis of the index catches and the resultant Bristol Bay run for the years 1956-1965, as shown in Table 28. The 24.4 million .3-ocean age return includes the Japanese high seas catch of immature .2-ocean age red salmon already removed in the summer of 1965, since in the regression analysis we have added into each years total for the Bristol Bay run of .3-ocean age red salmon an estimate of the preceding year's Japanese catch of immature .2-ocean age fish. The estimated Japanese catch of immature .2-ocean age red salmon in the summer of 1965 is 0.8 million (ref. Table 3). Subtracting this from the forecasted return of 24.4 million .3-ocean age fish gives an expected return of 23.6 million .3-ocean age fish and a total return of 34.0 million red salmon in 1966.

It should be pointed out with respect to Table 28 that the average index catch for all years has been calculated on a new basis in which sets are included only to a distance of 50 miles. Offshore, and the index period has been redefined as beginning on June 11 and continuing through August 10. Within this time range averages were calculated for 3 time periods (June 11-30, July 1-20, and July 21-August 10). The average index catches within each of these periods were then summed and divided by 3 to give the season's index. The change largely eliminates the effect of the different dates of commencement and termination of indexing and also gives equal weight to three parts of the season during which index operations were conducted.

The basic assumptions underlying the high-seas index are the same as in previous years as follows:

1. The seine catches are proportional to the abundance of immature reds passing through the index area each year.

2. The flow of reds passing through the index area contains a major and relatively constant proportion of the immature Bristol Bay reds at sea.

3. The flow of reds passing through the index area contains a high and relatively constant proportion of reds of Bristol Bay origin.

Extrapolation from the seine catch data as to total numbers of fish passing Adak Island, and tag returns and age composition analysis indicate that assumptions 2 and 3 are reasonably satisfied. Assumption 1 is open to question and plans for future index work include intensified sampling by an FRI seiner and by Bureau of Commercial Fisheries gill net vessels to test the validity of the assumption.

Qualifying Factors

The following factors could grossly affect the 1966 forecast but have not been used to modify the forecast because of insufficient data to evaluate their effect.

The efficiency of the index is directly dependent upon the width of the band of fish and the period of migration. In 1965 a good series of index sets was obtained extending to a distance of 80 miles from shore. Fish were shown to be present in substantial numbers to the full 80 miles sampled. Maximum abundance was apparently between the 20- and 40-mile distance. Although there are insufficient data to evaluate the width of the band with respect to previous years of indexing, such an observation does give us confidence that the 1965 index is not the result of fortuitous sampling in the belt of chief abundance. With respect to the time of passage, the .1 age fish appeared in substantial numbers through the entire period June 10 through August 20. The .2-ocean immatures did not appear in substantial numbers until July 17, but after that they continued through August 17 with no periods of serious decline as was observed in some previous years. Again such uniformity of abundance throughout a period of time lends support to the validity of the 1965 index.

Sizes of Immature Salmon in Index Catches

Both the .1-age and .2-age immatures in the index catches in 1965 were average size (35.6 and 48.1 cm, respectively) suggesting that fish in the Bristol Bay fishery will be of average size in 1966.

Table 28. Average Catch Per Index Seine Set of Immature Red Salmon South of Adak Island Compared with the Following Year's Bristol Bay Return.

Year of Index Catch	Average catch/set .1-ocean	.2-ocean	Year of Bristol Bay Run	Bristol Bay total run (millions)[1] .2-ocean	.3-ocean	total
1956	7.5	16.7	1957	5.4	16.3	21.5
1957	3.5	8.3	1958	3.9	4.1	8.0
1958	27.4	3.7	1959	12.3	3.0	15.3
1959	94.6	15.3	1960	34.8	7.8	42.6
1960	6.7	14.4	1961	7.9	18.4	26.3
1961	22.5	2.4	1962	8.1	4.2	12.3
1962	24.2	10.9	1963	4.6	4.0	8.6
1963	53.2	8.0	1964	9.8	3.6	13.4
1964	100.7	7.0	1965	55.2	7.9	63.1
1965	25.3	29.6	1966	10.4 [2]	24.4 [2]	34.8

1/ Including high seas catch of Bristol Bay red salmon.

2/ 1966 forecast values based on linear regression equations:

$R_2 = 0.481 + 0.431\ C_1$

$R_3 = -0.363 + 0.837\ C_2$ where,

R_2 : is .2-ocean age return
R_3 : is .3-ocean age return
C_1 : is .1-ocean age index catch
C_2 : is .2-ocean age index catch.

VI. Forecast of Total .3-ocean Returns Based on .2-ocean Returns in the Previous Year

Bristol Bay red salmon commonly spend two years or three years in the ocean and the relation of the return after three years to the return after two years may be used to forecast the expected total return of .3-ocean age red salmon. For this purpose the Bristol Bay run has been separated into three components: (1) Bristol Bay excluding the Kvichak River with 5_2 and 6_3 age classes combined; (2) Kvichak River, 6_3 age class; (3) Kvichak River, 5_2 age class.

The reasons for separating the Bristol Bay run into three components for the 1966 forecast rather than treating the Bay as a unit as in previous forecasts are as follows:

(i) During the past 10 years (1956-1965), the Kvichak run has been the dominant run in the Bay, particularly with respect to .2-ocean fish. In 1965, the Kvichak accounted for about 80 percent of the total run of .2-ocean sockeye. Over the preceding 9 years, the Kvichak accounted for about 40 percent of the total run of .2-ocean sockeye in the Bay. Separation of the dominant run from the other river systems represents a refinement in forecasting.

(ii) In 1965, practically the entire run of .2-ocean fish in the Kvichak consisted of 5_2 sockeye whereas in previous years (1956-1964) 4_2 sockeye accounted for over two-thirds of the Kvichak run of .2-ocean fish. There is a substantial quantity of evidence which indicates that maturity schedules differ for different fresh-water age groups of sockeye; namely, that a higher proportion of the sockeye of older fresh-water age mature as .2-ocean fish than sockeye of younger fresh-water age. In view of this evidence and the great reversal in the fresh-water age composition of .2-ocean sockeye in the 1965 Kvichak run, it is necessary to make separate forecasts for the 5_2 and 6_3 sockeye runs to the Kvichak in 1966.

Data and forecasts for each of the three components of the Bristol Bay .3-ocean return in 1966 are given in Tables 29, 30, and 31.

Table 29. Size of Return of .2- and .3-ocean Red Salmon in Successive Years, and Forecast of Run of .3-ocean Red Salmon in 1966 for Bristol Bay, Excluding the Kvichak River. (In millions of fish).

Year	Return of .2-ocean fish	Year	Return of .3-ocean fish
1956	6.578	1957	7.325
1957	2.486	1958	3.239
1958	3.406	1959	2.883
1959	11.395	1960	7.665
1960	10.865	1961	10.122
1961	1.880	1962	2.469
1962	4.820	1963	3.709
1963	4.245	1964	3.420
1964	8.241	1965	7.197
1965	9.319	1966	7.767 1/

1/ 1966 forecast based on linear regression:

$R_3 = 0.964 + 0.730\, R_2$ where,

R_3 : is .3-ocean age return and

R_2 : is .2-ocean age return.

Table 30. Size of runs of 5_3 and 6_3 red salmon in successive years and forecast of run of 6_3 red salmon in 1966 for the Kvichak River (in millions of fish).

Year	Run of 5_3 fish	Year	Run of 6_3 fish
1956	3.216	1957	1.164
1957	2.844	1958	0.808
1958	0.364	1959	0.072
1959	(0.642) 1/	1960	(0.000) 1/
1960	(0.568) 1/	1961	(0.587) 1/
1961	5.769	1962	1.456
1962	3.176	1963	0.285
1963	0.127	1964	0.032
1964	(0.210) 1/	1965	(0.013) 1/
1965	45.518	1966	11.456 2/

1/ Excluded from analysis because age classes were not adequately represented in samples.

2/ 1966 forecast based on linear regression:

$$R_{6_3} = -0.015 + 0.252\, R_{5_3}$$ where,

R_{6_3} : is 6_3 age return and

R_{5_3} : is 5_3 age return.

Table 31. Size of runs of 4_2 and 5_2 red salmon in successive years and forecast of 5_2 red salmon in 1966 for the Kvichak River (in millions of fish).

Year	Run of 4_2 fish	Run of 5_2 fish
1956	11.553	7.836
1957	0.088	0.076
1958	0.081	0.035
1959	0.251	0.147
1960	23.400	7.699
1961	0.217	0.272
1962	0.073	0.053
1963	0.198	0.147
1964	1.336	0.684
1965	0.324	0.431 1/

1/ 1966 forecast based on linear regression:

$R_{5_2} = 0.308 + 0.381\ R_{4_2}$ where,

R_{5_2} : is 5_2 age return and

R_{4_2} : is 4_2 age return.

VII. Forecast of Total .2-ocean Return

With an estimate of the total .3-ocean return and an independent estimate of the ocean age composition of the total return it is possible by ratio analysis to forecast the total .2-ocean return. The forecasted total .3-ocean return and ocean age composition based on the forecast from the high seas purse seine catches can be used to form this ratio. The data and forecast are as follows:

total .3-ocean forecast: 19.7

high seas purse seine,

.2-ocean	10.4
.3-ocean	24.4
Total	34.8

ratio analysis:

$$\frac{R_2}{R_2 + 19.7} = \frac{10.4}{34.8}$$

$R_2 = 8.4$ where

R_2 : is total .2-ocean return.

Table 32. Summary of Forecasts of the Bristol Bay Red Salmon Run in 1966 (in millions of fish).

	.2-ocean	.3-ocean1/	total
Forecast by River System			
Togiak	.091	.222	.313
Igushik	.139	.414	.553
Snake	.007	.004	.011
Nuyakuk	.037	.204	.241
Wood	1.950	.466	2.416
Nushagak-Mulchatna	.002	.045	.047
Nushagak Sub-total	2.135	1.133	3.268
Kvichak	14.819	6.408	21.227
Naknek	.515	1.352	1.867
Alagnak	.104	.087	.191
Naknek-Kvichak Sub-total	15.438	7.847	23.285
Egegik	1.338	1.837	3.175
Ugashik	.366	.864	1.230
North Side Alaska Peninsula	.834	.549	1.383
River System Total	20.202	12.452	32.654
High Seas Purse Seine	10.4	23.6	34.0
Relation of .3-ocean returns to .2-ocean returns		19.654	
Ratio estimate of .2-ocean return	8.4		

1/ The .3-ocean return has been adjusted by subtracting the Japanese high seas catch of immature red salmon in 1965.

Data Sources

International North Pacific Fisheries Commission, 1962.
"The exploitation, scientific investigation and management of salmon (genus Oncorhynchus) stocks on the Pacific Coast of the United States in relation to the abstention provisions of the North Pacific Fisheries Convention," Bulletin Number 10, pp. 158.

Manzer, J.I., T. Ishida, A.E. Peterson, and M.G. Hanavan, 1965.
"Salmon of the North Pacific Ocean - Part V," International North Pacific Fisheries Commission, Bulletin Number 15, pp. 452.

Burgner, R. L., 1965.
"Age composition of Nushagak sockeye runs by river system, 1950-1964," Fisheries Research Institute, Circular No. 234, Mimeo pp. 14.

DiCostanzo, Charles and Herbert Jaenicke.
"Statistics: Naknek-Kvichak, Egegik and Ugashik red salmon, 1957-1962". U. S. Bureau of Commercial Fisheries, Auke Bay, Alaska. Preliminary mimeo. data tables.

Jaenicke, Herbert.
Naknek River smolt data provided in tabular form for the years 1955-1965. U. S. Bureau of Commercial Fisheries, Auke Bay, Alaska.

Siniff, Donald B., 1964.
"Bristol Bay red salmon, 1963 - a compilation of the catch and escapement data," Alaska Department of Fish and Game, Informational Leaflet #35, pp. 181.

Pennoyer, S. and Mel Seibel, 1964.
"Bristol Bay red salmon, 1964 - a compilation of the catch and escapement data," Alaska Department of Fish and Game, Informational Leaflet #45, pp. 181.

_____, 1966.
"Bristol Bay red salmon (Oncorhynchus nerka), 1965 - a compilation of the catch and escapement data," Alaska Department of Fish and Game, Informational Leaflet #75, pp. 115.

_____, 1965.
"1964 Kvichak River red salmon (Oncorhynchus nerka) smolt studies," Alaska Department of Fish and Game, Informational Leaflet #58, pp. 43.

Nelson, Michael L., 1965.
"Abundance, size, age and survival of red salmon smolts from the Ugashik Lakes system, Bristol Bay, 1964," Alaska Department of Fish and Game, Informational Leaflet #62, pp. 34.

_____, 1966.
"Abundance, size and age of red salmon smolts from the Wood River Lakes system, 1965," Alaska Department of Fish and Game, Informational Leaflet #76, pp. 32.